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SYNCHRONOUS ORBIT BATTERY CYCLER

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— GODDARD SPACE FLIGHT CENTER —
GREENBELT, MARYLAND

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ABSTRACT

A device has been developed to simulate the charge/discharge cycling a battery will experience in a synchronous orbit satellite. This device will be used in battery testing to establish design parameters and battery performance for synchronous orbit use.

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SYNCHRONOUS ORBIT BATTERY CYCLER

INTRODUCTION

A satellite in a synchronous orbit has a fixed orbit period of one day, but the shadow portion of the orbit changes daily. For the first 21 days, the shadow period increases in daily increments from 0 to 70 minutes; then, for the next twenty-one days, the shadow period decreases in daily increments from 70 to 0 minutes. This is graphically illustrated in Curve A, Figure 1, showing the changing shadow period of a synchronous orbit satellite.

Prior to the Synchronous Orbit Battery Cyclus, the shadow was simulated at Goddard Space Flight Center, (GSFC), and the Naval Ammunition Depot (NAD), Crane, Indiana, by manually switching the battery into discharge for the required period of time each day. This method requires monitoring by personnel on a daily basis and leads to human error. Consequently, the Synchronous Orbit Battery Cyclus was developed to decrease the man-hours required for testing, thus eliminating this inherent error and providing more realistic test results.

This Synchronous Orbit Battery Cyclus will approximate the charge-discharge (light-shadow) cycling a battery will experience in a synchronous orbit satellite, without the operator making any adjustments after the initial alignment procedure is completed. The discharge, time profile produced by this Cyclus is shown in Curve B, Figure 1.

DESIGN PHILOSOPHY

Functional Description

A block diagram of the Synchronous Orbit Battery Cyclus is shown in Figure 2. The 24-hour clock controls the simulated orbit period by producing the appropriate signals that initiate the shadow period. These signals simultaneously set the charge-discharge control in the discharge mode, preset the discharge-time counter, start the discharge clock, and increase or decrease the orbit counter or day counter by one count.

The orbit counter counts and stores the number of orbits (days) up to 21. After the 21st orbit, the counter reverses and begins to count down. In the down count, a count of 20 represents the 22nd orbit; a count of 19 represents the 23rd orbit, etc.

The discharge clock generates pulses at two rates to the discharge-time counter, one pulse/7.5 minutes or one pulse/0.77 minutes. The pulse rate is determined by the clock frequency control.

The discharge-time counter counts the pulses from the discharge clock. Every count in the discharge-time counter represents a discharge time of 7.5 minutes, until the counter reaches eight. The count of eight is sensed by the discharge clock frequency control, which changes the discharge clock pulse rate to one pulse /0.77 minutes. Therefore, every pulse, after a count of eight is reached by the discharge-time counter, represents 0.77 minutes of discharge time. This accounts for the change of slope during both the increasing and decreasing portions of Curve B, Figure 1.

The comparator compares the orbit number accumulated in the orbit counter, with the discharge time accumulated in the discharge-time counter in increments of 7.5 and 0/.77 minutes. When both counters register an identical count, a pulse is sent to the charge-discharge control which stops battery discharge and switches to the battery charge mode.

Operation

In operation, with the cyclor in the charge mode, the simulated orbit begins when the 24-hour clock sends the signals to begin the discharge mode. When the discharge-time counter has received enough pulses from the discharge clock so its count equals that of the orbit counter, the comparator sends a pulse to the charge-discharge control to end discharge and begin charge. The cyclor remains in this charge mode until the 24-hour clock sends the signals to begin another discharge and, consequently, another simulated orbit. This cycling continues, the discharge time increasing with each orbit up to 21 days. At 21 days, the orbit counter reverses and begins counting down with each pulse from the 24-hour clock; and thereby, the discharge time decreases with each successive orbit. When the orbit counter reaches zero in the down count (42nd orbit), it is inhibited from receiving any additional counts, thus the battery remains on charge until both counters are manually preset, which places the cyclor in its initial charge state, and the charge-discharge cycling can be repeated for another 42 simulated orbits. Figure 3 is a diagram depicting the timing of a typical simulated orbit, orbit No. 2.

CIRCUIT DESCRIPTION

A schematic diagram of this unit is shown in Figure 4. The 24-hour clock consists of clock mechanism M-1, relay K-3, one-shot multivibrator O.S.-1, and their associated circuitry. The M-1 unit is a mechanical 24-hour timer. The contacts of this timer are closed once every 24 hours, allowing capacitor C-15 to discharge through the coil of K-3, thereby producing two momentary contact closures. Thus, closing contacts 1 and 3 presets the discharge-time counter, and closing contacts 6 and 8 supplies 24 vdc to the pulse forming circuitry which triggers O.S.-1. The O.S.-1 module and its associated circuitry form the

negative pulse which increases or decreases the orbit counter by one count. Simultaneously, opening contacts 5 and 8 de-energizes K-1 in the charge-discharge control section, which consequently starts the discharge clock and switches the cyclor into the discharge mode.

The orbit counter is a standard, binary, up-down counter which consists of flipflop modules F.F.-1 through F.F.-5 and logic modules G-1 thru G-6. The reversing circuit consists of G-7, G-8A, G-16A, and F.F.-6. When the counter reaches a count of 21, the output of gate module G-7 changes to the +3.0 vdc level. This dc voltage signal is inverted by G-8A and used to trigger F.F.-6 into the "1" state; thus converting the counter to a down counter. Module G-16A and its associated circuitry holds the count of 21 in the counter while it is being changed to the count-down mode of operation. Diodes D-3 through D-8 and module G-16B produce the inhibit signal. When F.F.-1 through F.F.-5 are in the "0" state and F.F.-6 is in the "1" state, the output of G-16B is at the 3.0 volt level. This condition holds the flip-flops in their present state and prevents the counter from accumulating any counts.

The discharge clock consists of an RC network of either C-10, R25 and R26, or C-10, R56 and R57, plus the following components: D-13, Q-7, Q-8, F.F.-7 through F.F.-10, G-17, G-18, and all associated circuitry. The RC network determines the basic clock frequency. When capacitor C-10 charges to 10.0 volts, diode D-13 allows the capacitor to discharge, producing a pulse. The pulse is shaped by Q-7 and its associated circuitry, with cathode follower Q-8 used to trigger F.F.-7. Modules F.F.-7 through F.F.-10 and G-17 form a frequency divider. The divided clock frequency serves as one input of "OR" gate G-18A, which triggers the first stage of the discharge time counter.

The clock frequency control consists of G-18B, Q-18, and K-4. When the discharge-time counter reaches a count of 8, G-18B turns-off transistor Q-18, thus de-energizing K-4. With K-4 de-energized, the resistive component of the RC network in the discharge clock is changed from R25 and R26 to R56 and R57.

The discharge-time counter is a standard, binary counter consisting of F.F.-11 through F.F.-15.

The comparator consists of a series of exclusive or-gates G-8B through G-15, with a common output. When the count stored in both the orbit counter and the discharge-time counter is identical, the comparator sends a signal to the charge-discharge control section.

The major components of the charge-discharge control are K-1 and Q-9. The signal from the comparator turns-on silicon controlled rectifier (SCR) Q-9 which energizes K-1. This places the cyclor in the charge mode. When K-3

contacts 5 and 8 are opened momentarily, the lead to the anode of the SCR is opened, thus Q-9 is turned off. This de-energizes K-1 and places the cyclor in the discharge mode until another signal is received from the comparator.

Figure 5 is a photograph showing the top view, in particular, the printed circuit boards which contain most of the circuitry.

ADDITIONAL FEATURES

This self-contained cyclor has both a 3.6 volt and a 24 volt power supply. It also has ac power failure protection. If ac power fails, K-2 is de-energized, disconnecting the battery from the charger or load. Before K-2 can become energized again, manual reset must be initiated.

The counters have indicating lights on the "1" output of each stage for visual monitoring. In addition, there are switches to preset each counter and switches to count manually with each counter, if desired. The operator can also switch to the charge or discharge mode; lights indicate which mode has been selected. Figure 6 is a photograph showing the front view of a cyclor unit with the various switches and indicating lights.

The operation switch, SW-9, allows the operator to select manual or automatic operation. Automatic is the normal operating position; the manual position is used for prolonged charges and discharges. When SW-9 is in the manual position, the 24 hour timer and the discharge-time counter are inhibited. Therefore, the cyclor will stay in the same mode, charge or discharge, continuously until the operator changes it.

If a closer approximation to Curve A, Figure 1 is desired, it can be accomplished by adding circuitry to the clock frequency control and discharge clock sections. The number of pulse rates produced by the discharge clock can be increased from two to four by adding a gate and a relay to the clock frequency control section and resistors to the RC network in the discharge clock. This would add two additional changes of slope to both the increasing and decreasing portions of Curve B, Figure 1; therefore producing a closer approximation to Curve A.

Figure 7 shows a typical test configuration. At present, the cyclor can accommodate battery currents up to 10 amperes. If higher currents are desired or more than one battery is to be under test, K-1 can be used to drive other relays which have higher current contacts or several relays in parallel. Figure 8 is a rear view showing the jacks where the charger, battery, and load are interfaced with the unit.

STATUS

A prototype unit has been fabricated and satisfactorily tested. Also, two additional units have been fabricated and are presently being evaluated. Upon completion of the evaluation, one unit will be sent to the NAD, Battery Testing Facility, Crane, Indiana, for use in their testing program, and the other unit will be used here in the GSFC battery testing program.

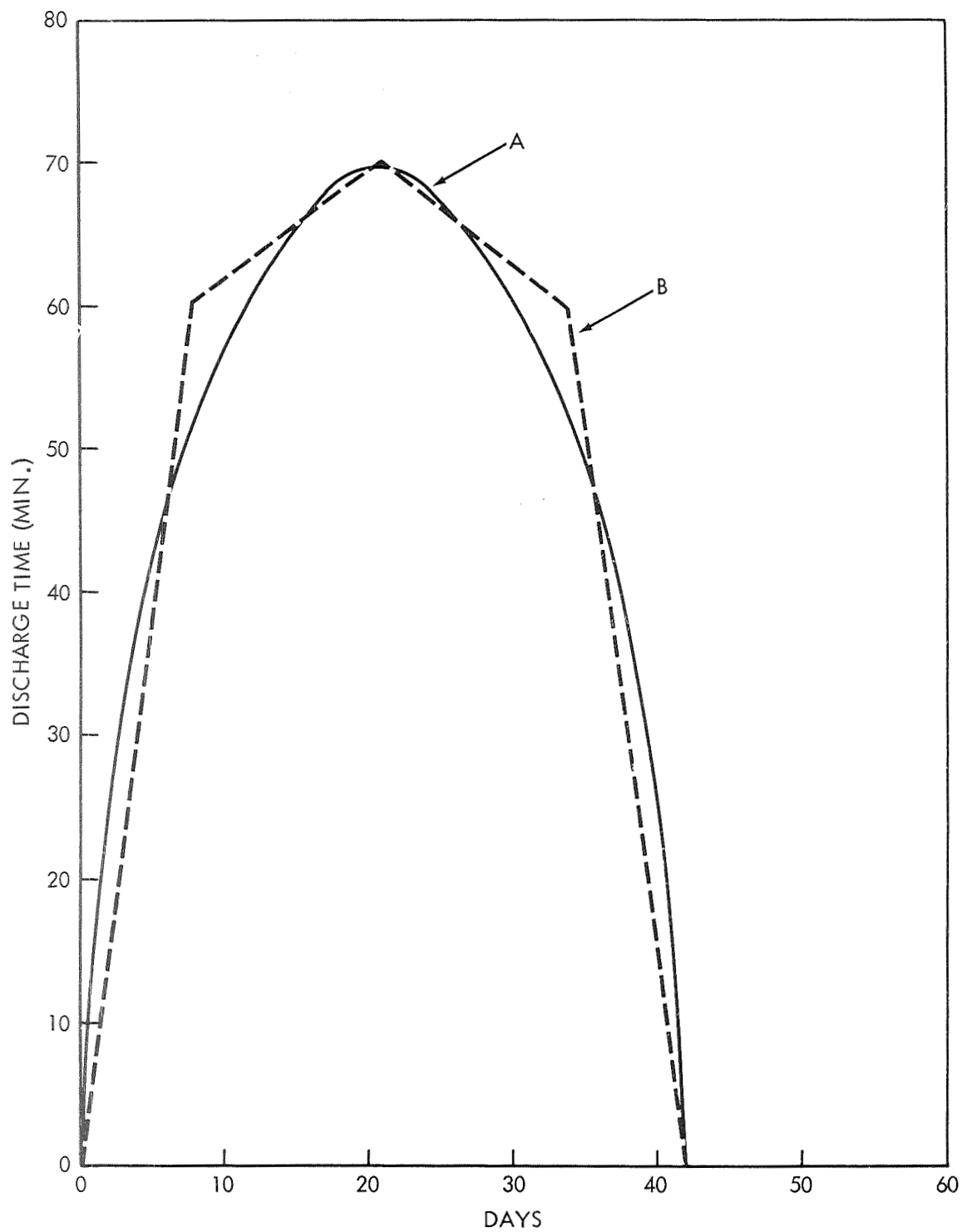


Figure 1. Discharge, Time Profile Produced by the Synchronous Orbit Battery Charger

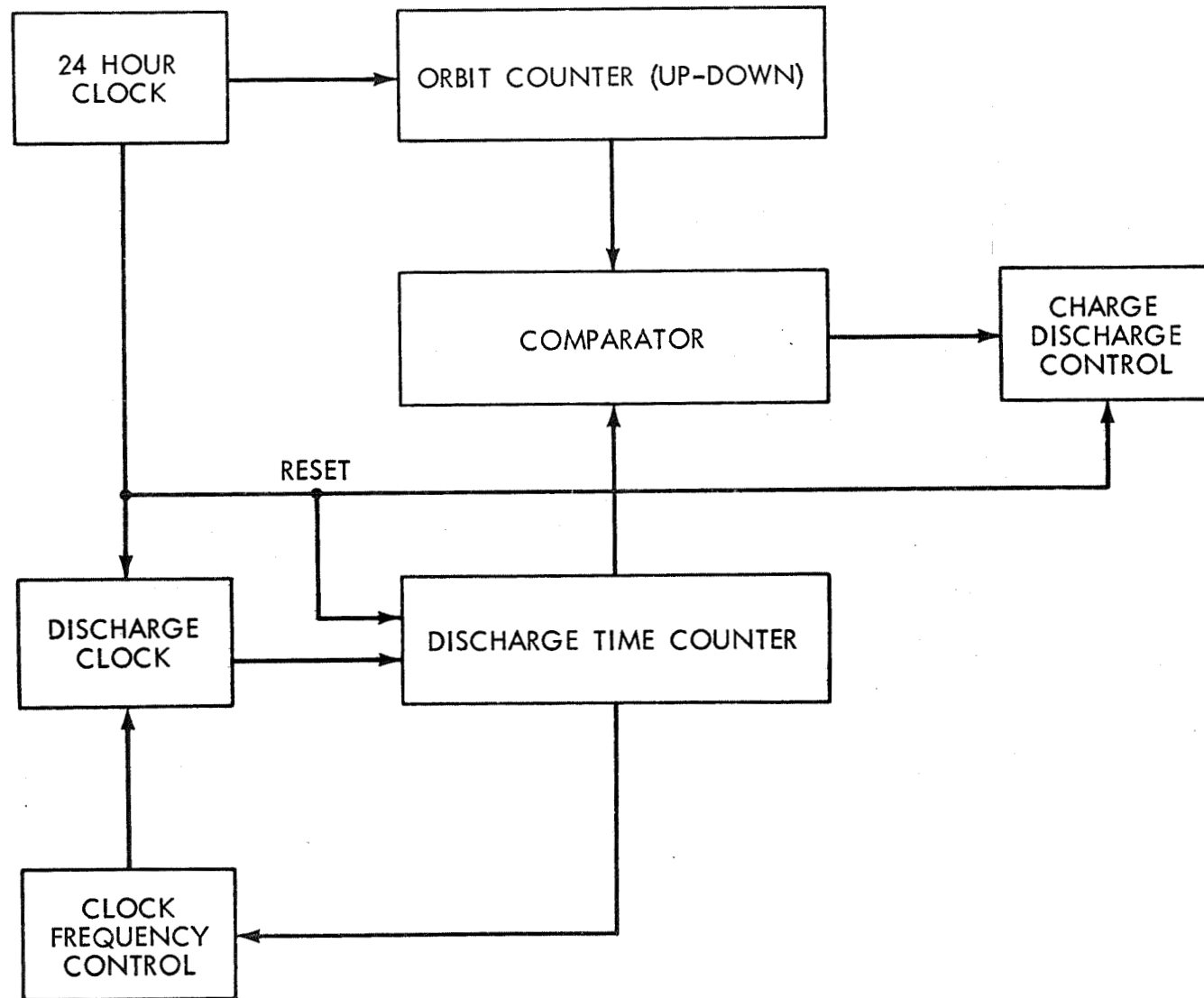


Figure 2. Block Diagram of the Synchronous Orbit Battery Charger

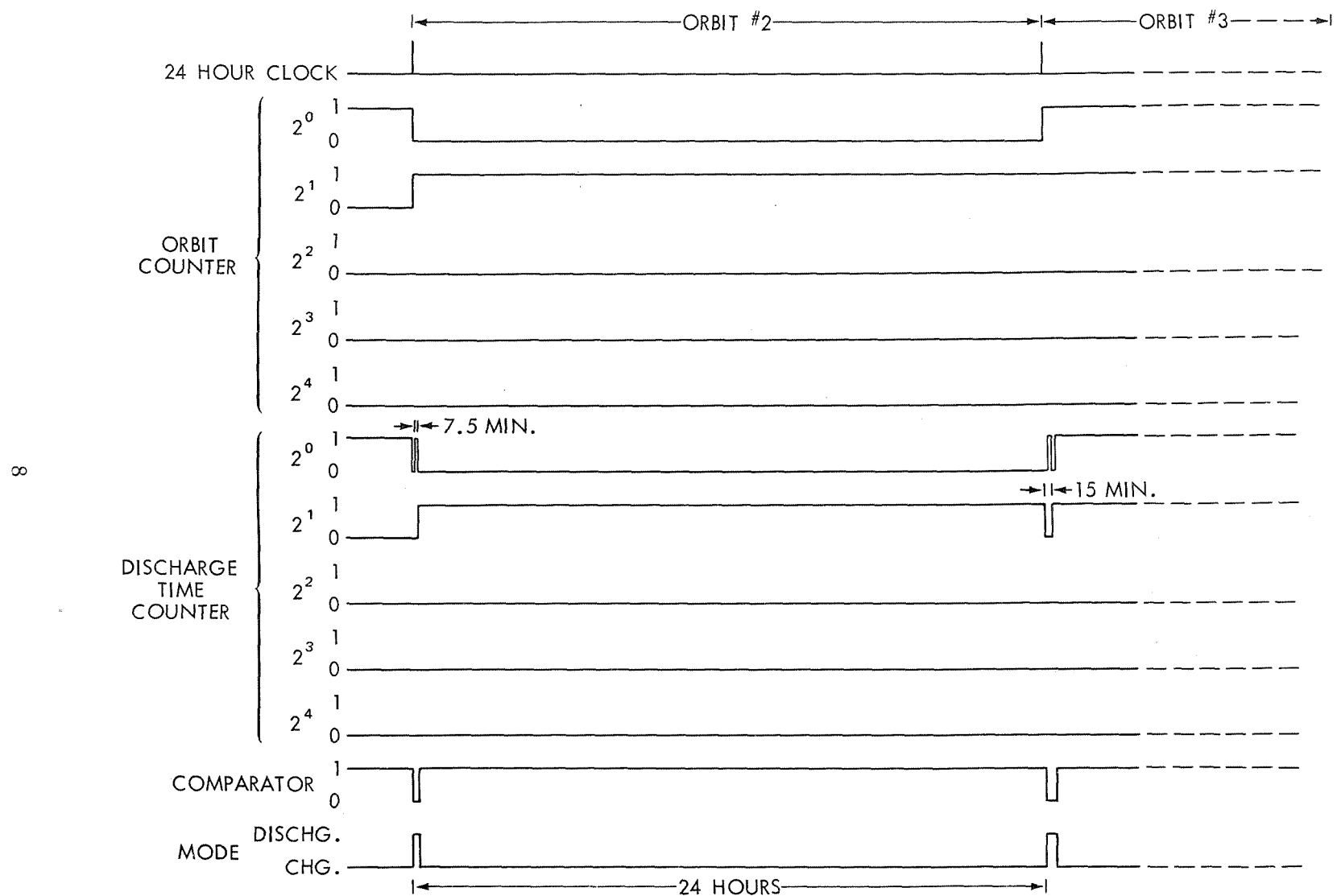


Figure 3. Timing Diagram

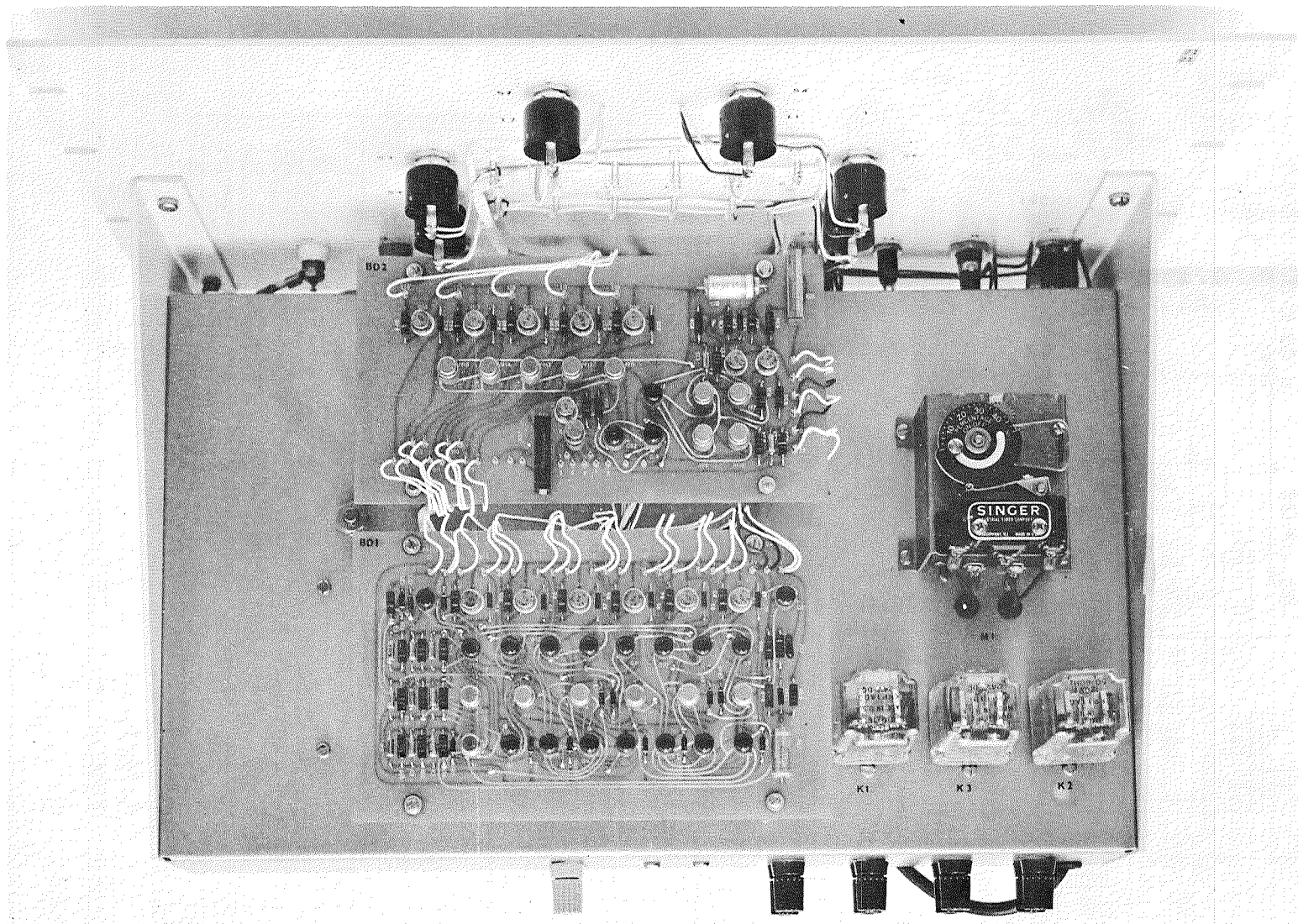


Figure 5. Top View of the Synchronous Orbit Battery Charger

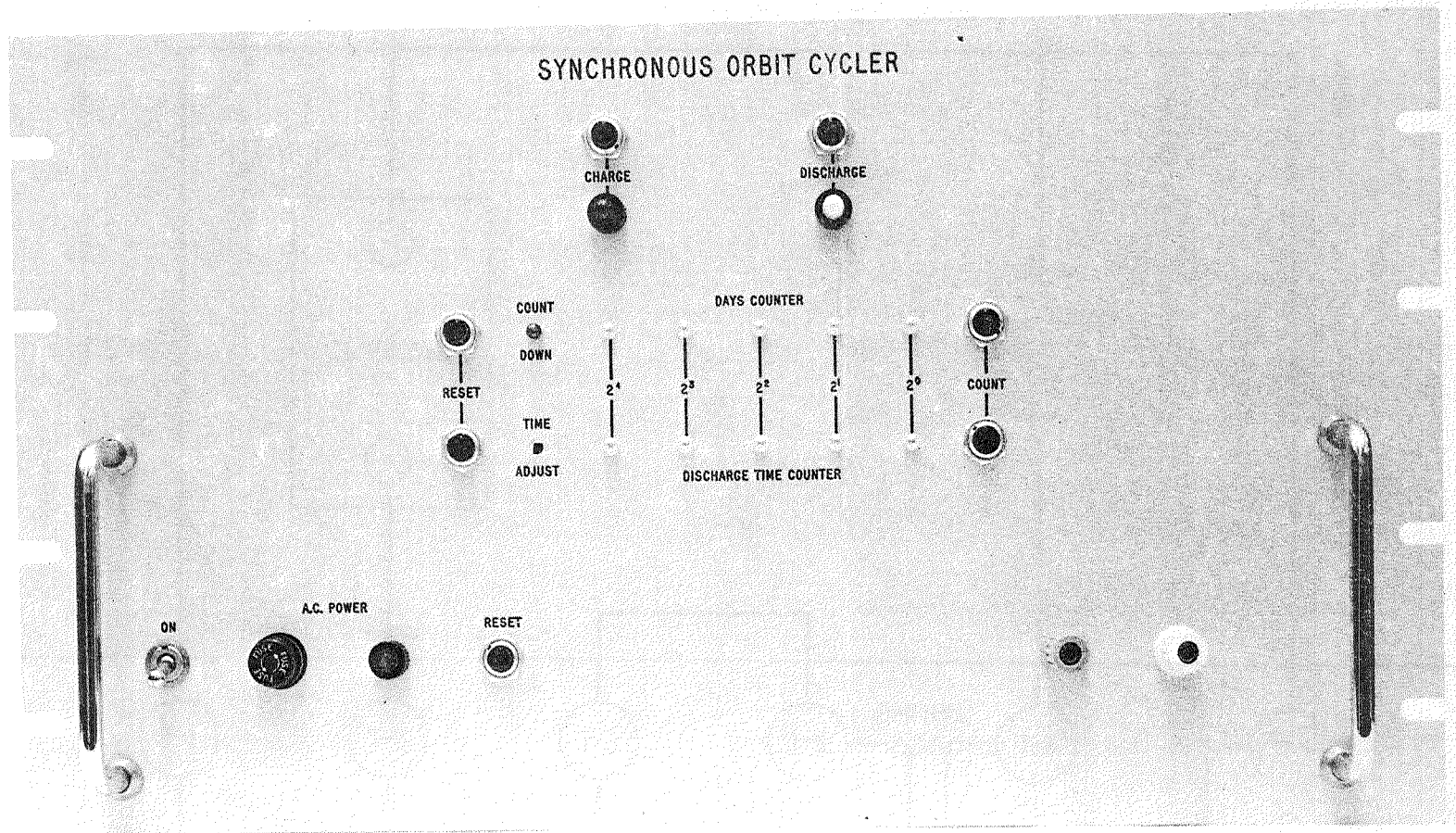


Figure 6. Front View of the Synchronous Orbit Battery Charger

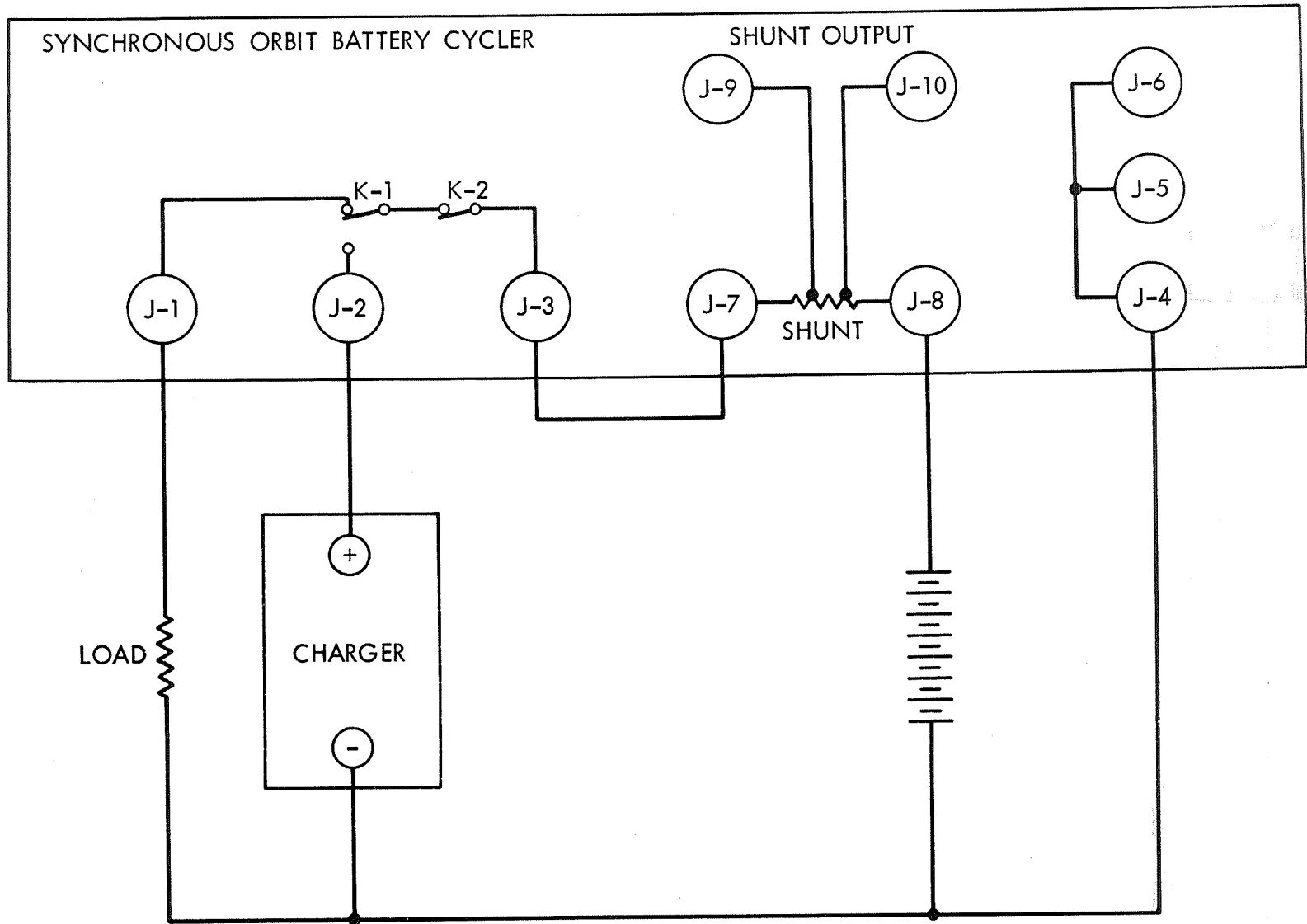


Figure 7. Typical Test Configuration

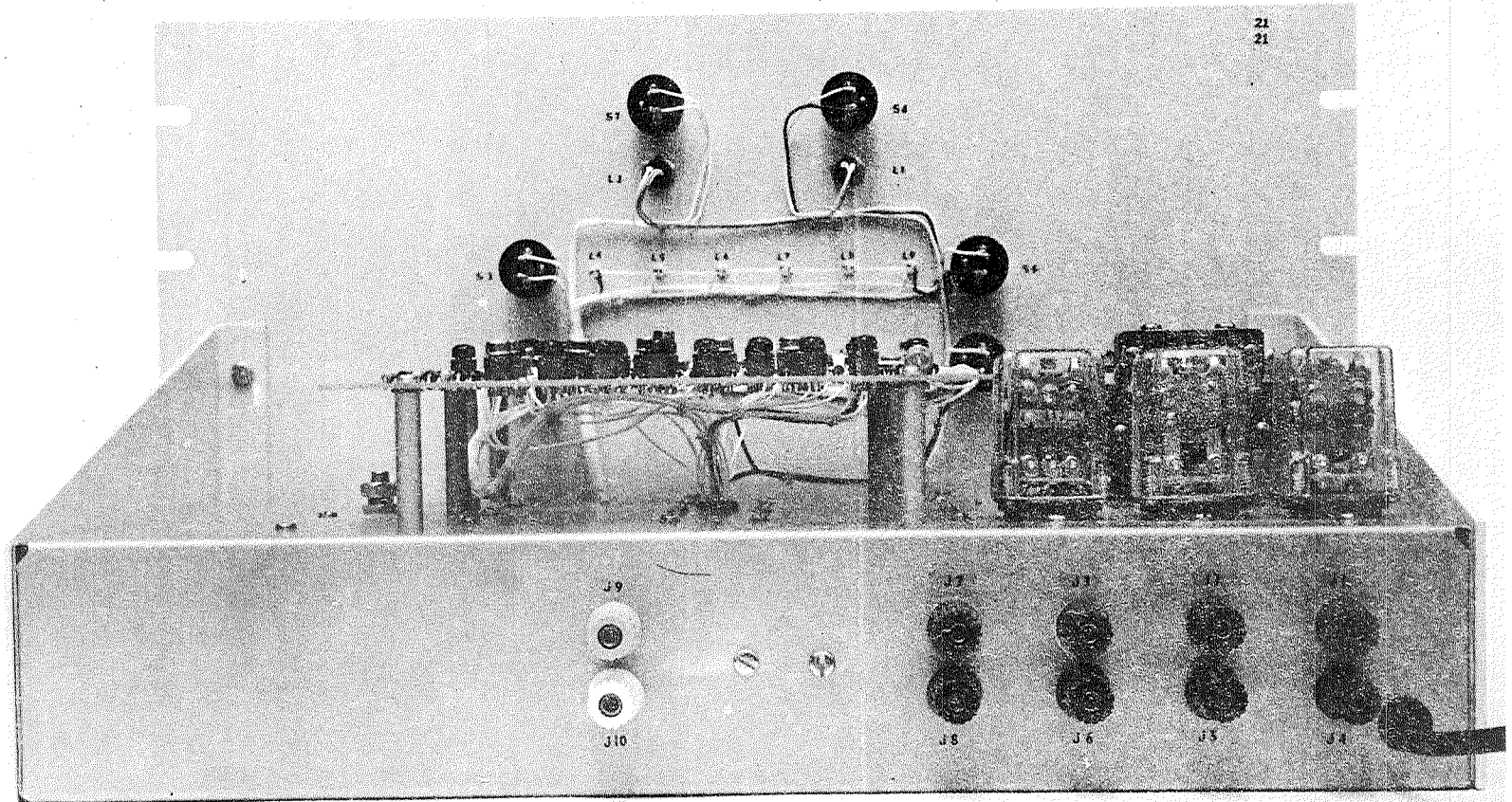


Figure 8. Rear View of the Synchronous Orbit Battery Charger

APPENDIX A

Parts List for Synchronous Orbit Battery Cycler

Part Number	Description
R1, R3, R5, R7, R9, R11, R24 R35, R37, R39, R41, R43, R55	1.5 K, 1/4 W, 5%
R2, R4, R6, R8, R10, R12, R14, R27, R34, R36, R38, R40, R42, R44	130Ω , 1/2 W, 5%
R13, R15, R16, R17, R18, R19, R20, R21, R22, R32, R46	51 K, 1/2 W, 5%
R23	3.3 K, 1/2 W, 5%
R25	50 K, 1/2 W, 25 turn trimpot
R26	698 K, 1/4 W, 1%
R28, R31, R54	300Ω , 1/2 W, 5%
R29, R30, R45, R49, R50	1 K, 1/2 W, 5%
R33	500 K, 1/2 W, 5%
R47	680Ω , 1/2 W, 5%
R48	330Ω , 1/2 W, 5%
R51	500 Ω Potentiometer 1/2 W AB TYPE G GA2GO28S501MA
R52	2 K, 1/2 W, 5%
R53	100Ω , 5 W, 10%
R56	10 K, 1/2 W, 25 turn, trimpot

Part Number	Description
R57	75 K, 1/4 W, 1%
C1, C2, C4, C5, C6, C7, C8 C9, C12, C13	.01 μ f, 35 VDC, Tantalum
C-3	.03 μ f, 35 VDC, tantalum
C-10	82 μ f, 35 VDC, tantalum
C-11	150 Pf mica
C-14	10 μ f, 35 VDC, tantalum
C-15	300 μ f, 30 VDC, tantalum
C16	47 μ f, 35 VDC, tantalum
C17	51 pf mica
C18, C19	500 μ f, 50 VDC, Electrolytic
C20, C21	2200 μ f, 25 WVDC, Type 39D Sprague #228G025HP4
D1, D2, D3, D4, D5, D6, D7, D8 D9, D10, D11, D12, D14	IN457
D13, D17	Four-layer M4L3054 Diode
D15, D16, D18, D19, D20, D21	IN4004
D22, D23, D27, D28	constant current diode MCL1304
D24	ZENER, IN3029B
D25, D26	IN250
D29	Low-voltage avalanche diode, LVA56A

Part Number	Description
Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8, Q10, Q11, Q12, Q13, Q14, Q16, Q18	2N697
Q9	SCR, 2N2323
Q15, Q17	2N3232
F.F. -1, thru F.F. -15	FLIP-FLOP, Fairchild μ L926 (f μ L92629-747)
G. -1 thru G18	GATE Fairchild μ L914 (f μ L91428-751)
I-1	Inverter Fairchild μ L927 (f μ L92729-829)
O.S. -1 and O.S. -2	BUFFER Fairchild μ L900 (f μ L90028-750)
L-1	DIALCO #39 28 V .04 A; RED LENSE, SOCKET #7538
L-2	DIALCO 507-3917 28 v, .04 A (WHITELENSE) SOCKET #7538
L-3	DIALCO NEON 45-56 k (YELLOW LENSE) SOCKET #7545
L-4, L-5, L-6, L-7, L-8, L-10, L-11, L-12, L-13, L-14	CAL-GLO COMPANY 1.5 volts .015 AMPS CLEAR LENSE BEP2CBP
L-9	CAL-GLO COMPANY 1.5 volts .015 AMPS YELLOW LENSE BEP2CBP
K-1	Potter & Brunfield KRP 14 DG 24 VDC

Part Number	Description
K-2	Potter & Brunfield KRP 11AG 115 VAC
K-3	Potter & Brunfield KRP 11DG 24 VDC
K-4	TELEDYNE 712-18
SW-1	SPDT - 5 AMPS 250 VAC
SW-2, SW-3, SW-4, SW-5 SW-6, SW-8	SPST, N.O., GRAYHILL #2201R
SW-9	DPDT, ARROW-HART #83050-1
SW-7	SPST, N.C. GRAYHILL #2202B
T-1	F-25 X Filament Transformer, TRIAD Transformer Corp.
T-2	F-40 X Filament Transformer, TRIAD Transformer Corp.
M-1	Industrial Timer Corp. Model CM12 A-12 GEAR.
J-1, J-2, J-3, J-7	Five-way Binding Posts (RED)
J-4, J-5, J-6, J-8	Five-way Binding Posts (BLACK)
J-9	Five-way Binding Posts (BLUE)
J-10	Five-way Binding Posts (WHITE)
SH-1	50 AMP 50 M.V. SHUNT (LIGHT- WEIGHT) Weston 148254 MSA 500

APPENDIX B

Adjustment Procedure for the Synchronous Orbit Battery Cyclor

1. Connect a TSI Universal Counter or equivalent between pin #3 of F.F.-11 and the bus called common.
2. Preset the discharge-time counter, set the cyclor for automatic operation in the DISCHARGE mode.
3. Adjust R-25 until the period between the pulses is 28.12 seconds.
4. Manually place a count of 8 in the discharge-time counter.
5. Adjust R-56 until the period between the pulses is 2.89 seconds.